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6. AUTHOR(S) Kim, Dongjin				5d. PROJECT NUMBER 4720000811	
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Korea Research Institute of Ships & Ocean Engineering 32 Yuseong-daero 1312beon-gil, Yuseong-gu, Taejeon, 305343, Republic of Korea				8. PERFORMING ORGANIZATION REPORT NUMBER	
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14. ABSTRACT I visited NSWC Combatant Craft Division in Norfolk. The high speed boats, including unmanned surface vehicles, are built and tested there. I investigated the recent trends of high speed boats in US and introduced the progress of our USV project. And I visited NSWC Carderock Division in Bethesda, and of course I also visited MASK facility and other basins in DTMB. I surveyed the recent high speed model tests in NSWC, and discussed whether our seakeeping and maneuvering planing boat model tests can be carried out in MASK's facilities. We discussed common interests on planing hulls, and made plans for collaboration studies between NSWC and KRISO.					
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16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			Kim, Dongjin
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1. Overview of the visit to NSWC

- Destination : Naval Surface Warfare Center, US
- Period : 8/17/2015 ~ 8/22/2015
- Purpose :
 - I am a researcher at Korea Research Institute of Ships and Ocean Engineering, and have performed the project titled as “Development of multi-purpose intelligent unmanned surface vehicle”, which is funded by the government of Republic of Korea. In that project, I have developed the planing hull forms for satisfying the requirements of the project. Model tests and analyses are required to assess the maneuvering and seakeeping performance of the designed planing hulls.
 - In particular, a large and well-equipped square basin is required to perform the seakeeping tests for the planing boat. I asked to Naval Surface Warfare Center (NSWC) whether the planing boat model tests can be carried out in MASK, and we were supposed to have more discussions about them.
 - At first, I visited NSWC Combatant Craft Division (CCD) in Norfolk. The high speed boats, including unmanned surface vehicles, are designed and built at CCD in Norfolk. So I hoped to investigate the recent trends of high speed boats in US and to introduce the progress of our USV project to the researcher in CCD.
 - And I visited NSWC Carderock Division in Bethesda, and of course I also visited MASK (Maneuvering and seakeeping basin) facility and other basins in DTMB (David Taylor Model Basin). I hoped to survey the recent high speed model tests in NSWC, and to discuss whether our seakeeping and maneuvering planing boat model tests can be carried out with MASK’s facilities such as wave makers or measuring systems. We were supposed to discuss common interests on planing hulls, and to make plans for collaboration studies between NSWC and KRISO as well.

2. Details

- Itinerary

Date	Contents
8/17/2015 (Mon)	• <u>Seoul /Korea-> New York -> Norfolk</u>
8/18/2015 (Tue)	• Visit to Combatant Craft Division • Discussion of developments of high speed boats and USV • <u>Norfolk -> Washington DC</u>
8/19/2015 (Wed)	• Visit to Carderock Division (MASK and other basin in DTMB) • Presentation of USV project in KRISO • Discussion of common interests about planing hulls • Planning for collaboration studies between NSWC & KRISO
8/20/2015 (Thu)	• Review of discussions and sharing data • Summary and report
8/21/2015 (Fri) ~ 8/22/2015 (Sat)	• <u>Washington DC -> Seoul/Korea</u>

- Visit to Naval Surface Warfare Center Combatant Craft Division (NSWCCCD)

Combatant Craft Division (CCD) is the core of U.S. government high performance boat/craft expertise and experience, is located in Norfolk, USA. CCD conducts waterfront operations in support of engineering, test and evaluation, demonstration. There are manned and unmanned combatant craft, boats, and advanced marine vehicles. Some projects of development of high speed combatant crafts are in progress, in particular, unmanned surface vehicle (USV) tests are performed in CCD.

Several high speed crafts are anchored at the dock. Outboard stern drives are more than the inboard waterjets. Manned and unmanned modes are used for the USV. In unmanned modes, various levels such as waypoint tracking, autonomous operations are available depending on USV missions.

Overview of USV project in KRISO was presented in CCD as shown below slides.

Test facilities in KRISO

Towing tank



- 200m x 16m x 7m
- Carriage : Max. speed 6m/s

Ocean Engineering Basin



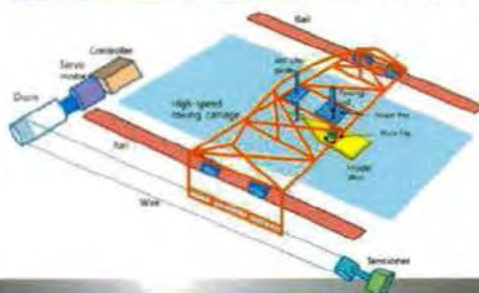
- 56m x 30m x 4.5m
- CPMC carriage

• <http://www.kriso.re.kr/enr/study/facilities.html>

Test facilities in Seoul National University(SNU)



- Towing tank dimension
: 117.0m x 8.0m x 3.5m
- Max. speed of carriage : 10m/s



• "Theoretical prediction of turning attitude of a semi-displacement round-bulge vessel at high speed" Applied Ocean Research, 2013

Aim of our USV project



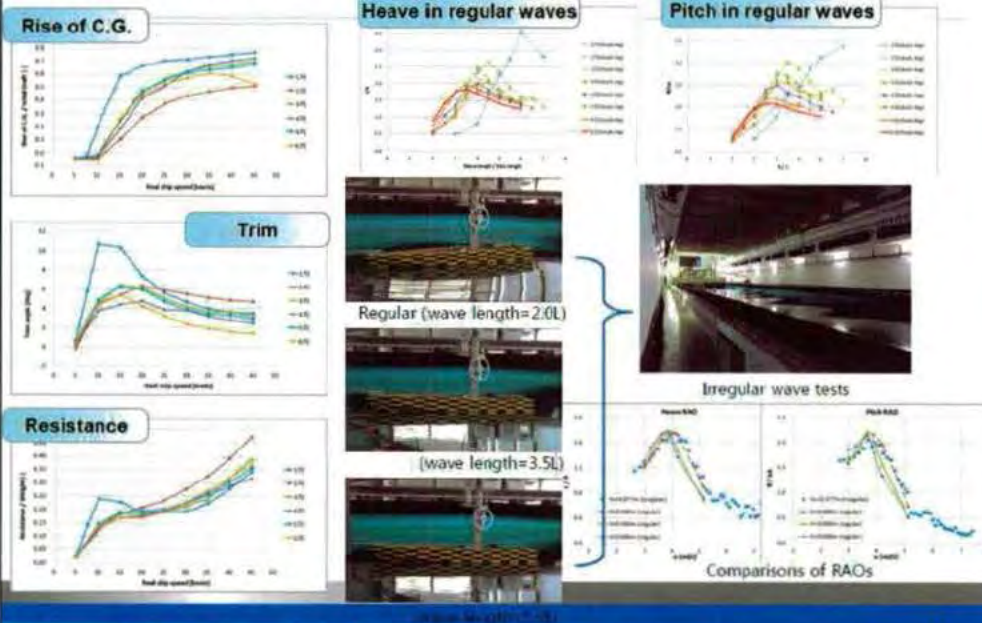
- 3.0 ton class, waterjet propelled
- Above 45 knots in calm water
- Operable up to Sea state 4



<http://www.korea.ac.kr/eng/study/sea404.html>

6

Towing model(1/6.5) test in SNU tank



- Design of high-speed planing hulls for the improvement of resistance and seakeeping performance: SIMACS-JHY-8
- Evaluation of a small and fast planing boat's seakeeping performance at the design stage: FAST-027 continuous

Full-scale & Free-running model(1/2.35) test in lake

< Full scale (Hull B2) >



High speed course-keeping test



Manoeuvring test

< Free running model (Hull C1) >



High speed course-keeping test



Manoeuvring test

• Improvement of course-keeping stability and manoeuvrability of water-jet propelled planing boats. F&E/2014, continuous

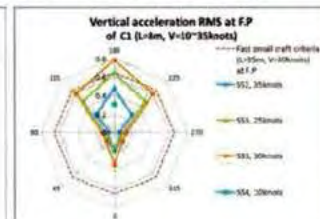
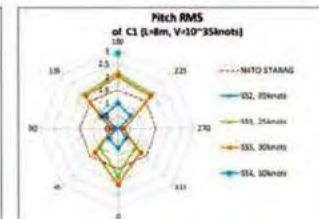
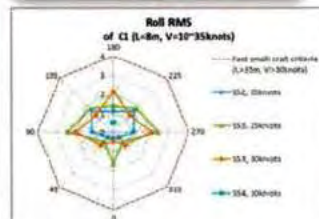
Free running model(1/6.5) test in ocean basin



Sea state	Speed [knots]
SS2	35
SS3	~ 30
SS4	~ 10



< SS3, 30knots, bow quartering >



• Evaluation of a small and fast planing boat's seakeeping performance at the design stage. F&E/2015, continuous

Collaboration studies between KRISO and NSWC are proposed as follows.

In short term,

- A. Seakeeping tests with higher speed, larger wave height
- B. Manoeuvring tests in waves

In long term,

- A. Correlation study between model and full-scale ship
- B. Improvement of accuracy and reliability of high speed model tests

- Visit of Naval Surface Warfare Center Carderock Division (NSWCCD)



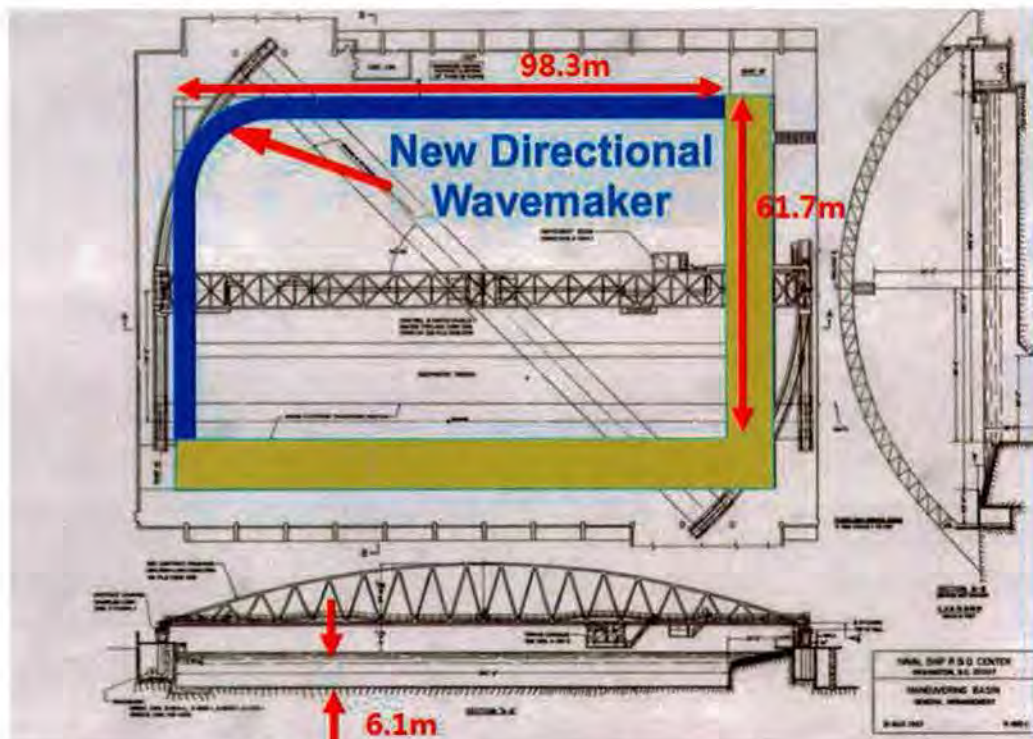
<Figure 1. Maneuvering and Seakeeping Basin(MASK)>

Carderock Division of Naval Surface Warfare center (NSWCCD) is a major component and field activity of the US naval sea systems command. NSWCCD addresses the full spectrum of applied maritime science and technology. This includes all technical aspects of improving the performance of ships, submarines, military water craft, and unmanned vehicles. David Taylor Model Basin (DTMB) is located at the facility.

I met Tim Smith, Simulations and Analysis Branch Head, and other researchers. I introduced KRISO USV project, we discussed about the common interest on high speed crafts.

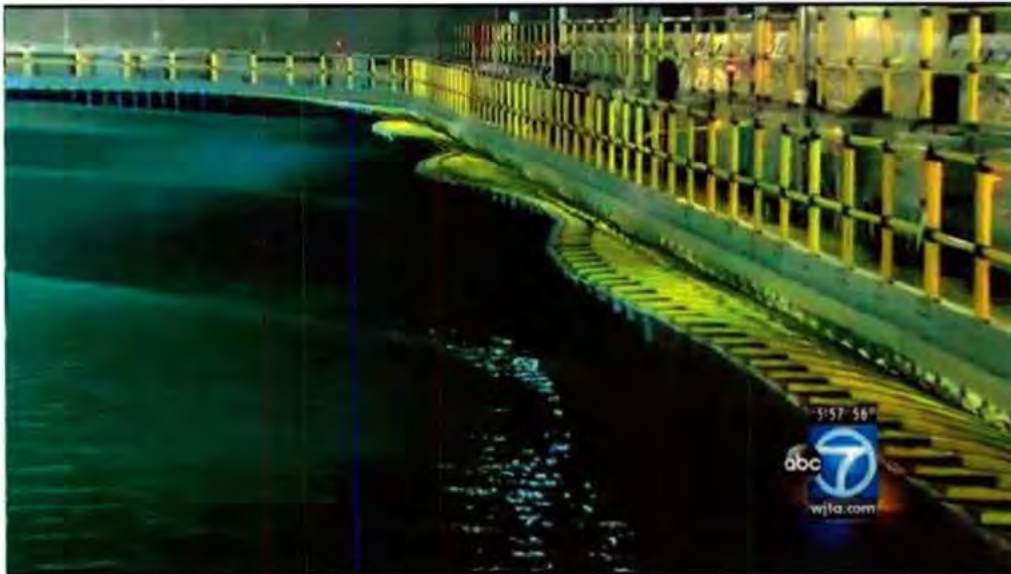
There are many similarities in hull design and test process between NSWCCD and KRISO. NSWCCD has large square basin, MASK (maneuvering and seakeeping basin). Several free running model tests, including maneuvering tests in waves, were performed in MASK.

Length and width of MASK is 100m and 60m, respectively. There is XY carriage and wave maker systems. Maximum height of regular waves is about 1.0 meter and that of irregular waves is 0.5 meter (shown in Figure 4). If our USV (3 ton, 8 meter, maximum speed 45 knots) model tests are performed in MASK, 1/6 model scale will be suitable for free running tests.

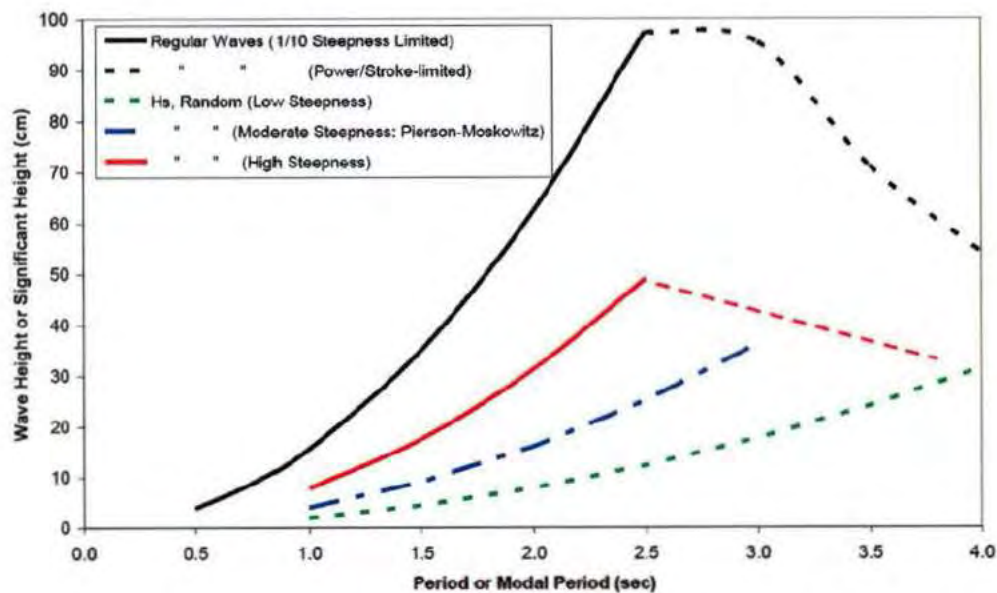


<Figure 2. Dimensions of MASK>

Wave makers are renewed in recent. As shown in Figure 3, there are 216 panels are arranged as L-shape.



<Figure 3. Wave maker operation in MASK>



<Figure 4. Wave heights and periods of generated by MASK wave makers>

<Table 1. Tank dimensions of DTMB>

Tank characteristics			
	Length [m]	Width [m]	Depth [m]
Shallow water basin	92	16	0~3
Deep water basin	575	16	7
High speed basin	905	6	3
140 foot basin	43	3	2

<Table 2. Maximum speed of carriages in DTMB>

Maximum speed of carriage [m/s]	
No.1 carriage (shallow water basin)	7.2
No.2 carriage (deep water basin)	10.3
No.3 carriage (high speed basin)	16.5
No.5 carriage (high speed basin)	25.7
No.6 carriage (high speed basin)	> 25.7
Carriage (140 foot basin)	3.1

I visited David Taylor Model Basin. There are two rows of towing tanks. In particular, the length of high speed basin is about 1 kilometer, and slamming model tests were carried out in recent. Table 1 and 2 show the DTMB tank dimensions and the maximum speed of carriages.



<Figure 5. Exterior view of DTMB>



<Figure 6. Interior view of DTMB>



<Figure 7. Example of high speed model test in DTMB>

In NSWC, there were several cases for collaboration studies with foreign institutes funded by ONR (Office of Naval Research). Therefore, if KRISO suggests research or test topics within common interests between two institutes, there is a good possibility that new collaboration researches or model tests will be performed in NSWC.

3. Summary

The purposes of this visit are the survey of recent trends of high speed craft development in Combatant Craft Division, and the discussion about the high speed model tests at MASK in Carderock Division of Naval Surface Warfare Center.

Combatant Craft Division seems to be major department for the high speed naval craft construction and operation. Many kinds of high speed ships are developed, and a lot of missions of them are tested. In particular, unmanned vehicles have various missions such as patrol, ocean survey, and mine sweeping, and so on. Unmanned levels (from waypoint tracking to fully autonomous operation.) are determined and given depending on their mission types.

Carderock Division has MASK, and DTMB facilities. There were many high speed model test cases in the facilities. KRISO USV project was introduced, and we share the common interests and recent research information of high speed crafts. KRISO is interested in the free running model tests for planing hulls in calm water and waves, MASK facilities will be available for the high speed free running model tests.

Short term and long term plans were proposed as shown below. We, KRISO hope to perform the collaboration studies by using excellent facilities of NSWC.

In short term,

- A. Seakeeping tests with higher speed, larger wave height
- B. Manoeuvring tests in waves

In long term,

- A. Correlation study between model and full-scale ship
- B. Improvement of accuracy and reliability of high speed model tests

4. Shared technical data


- KRISO to NSWC

a. Presentation file for the progress of USV project in KRISO




- b. Dongjin Kim et al., “Development of high-speed planing hull forms with consideration of resistance and seakeeping performance”, Proceedings of 18th International Conference on High Performance Marine Vessels (HPMV), 2013.
- c. Dongjin Kim et al., “Improvement of transverse and course-keeping stability of a water-jet propelled planing vessel”, Proceedings of 10th symposium on High Speed Marine Vehicles (HSMV), 2014.
- d. Dongjin Kim and Sunyoung Kim, “Evaluation of a small and fast planing boat’s seakeeping performance at the design stage”, Proceedings of 13th International Conference on Fast Sea Transportation (FAST), 2015.
- e. Dongjin Kim et al., “The effect of course-stabilizing fixed fins on manoeuvring performance of a water-jet propelled planing boat”, Proceedings of International Conference on Ship Manoeuvrability and Maritime Simulation (MARSIM), 2015.





- NSWC to KRISO
- a. Introduction of NSWC unmanned surface vehicles
- For example, 11 meter class USV has the maximum speed of 45 knots, and it can be operable up to sea state 5.



THE STILETTO SUPPORT FLEET

The vessels below represent only a small sample of the many boats Stiletto has in their support fleet.



 <p>NSW 11M RIB (Unmanned Capable)</p>	<table border="1" style="width: 100%; border-collapse: collapse;"> <tr><td>BUILDER</td><td colspan="2">USMI</td></tr> <tr><td>LENGTH</td><td>36 FT</td><td>BEAM</td><td>10 FT 6 IN</td></tr> <tr><td>DRAFT TO KEEL (FULL LOAD)</td><td colspan="3">3 FT</td></tr> <tr><td>SPEED (FULL LOAD)</td><td colspan="3">45 KTS</td></tr> <tr><td>ENGINE</td><td colspan="3">TWIN 3126 CATERPILLAR DIESEL ENGINES</td></tr> <tr><td>DRIVES</td><td colspan="3">2 WATER JET DRIVES</td></tr> <tr><td>CREW</td><td colspan="3">3 PERSONS</td></tr> <tr><td>FULL LOAD CAPACITY (INCLUDING CREW)</td><td colspan="3">11 PERSONS</td></tr> <tr><td>FULL OPERABILITY, REDUCED SPEED</td><td colspan="3">SEA STATE 5</td></tr> <tr><td>RANGE</td><td colspan="3">GREATER THAN 200 NM</td></tr> </table>	BUILDER	USMI		LENGTH	36 FT	BEAM	10 FT 6 IN	DRAFT TO KEEL (FULL LOAD)	3 FT			SPEED (FULL LOAD)	45 KTS			ENGINE	TWIN 3126 CATERPILLAR DIESEL ENGINES			DRIVES	2 WATER JET DRIVES			CREW	3 PERSONS			FULL LOAD CAPACITY (INCLUDING CREW)	11 PERSONS			FULL OPERABILITY, REDUCED SPEED	SEA STATE 5			RANGE	GREATER THAN 200 NM		
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<p>THE FOLLOWING ASSETS ARE ALSO AVAILABLE TO ASSIST THE STILETTO PROGRAM</p>																																								
<p>82' MAKO 40' UTILITY CRAFT (UC) 39' UNMANNED SEA SURFACE VEHICLE-HIGH TOW FORCE (USSV-HTF) 38' SMALL UNIT RESERVE CRAFT (SURC) 35' AUTONOMOUS MARITIME NAVIGATION (AMN2) 34' UNMANNED SEA SURFACE VEHICLE-HIGH SPEED (USSV-HS) 10M NSW RIB 22' UTILITY BOAT 6M UTILITY CRAFT (SMUC-SMUCM)</p>	<p>41' COAST GUARD UTILITY BOAT (CG-UB) 40' UNMANNED INFLUENCE SWEEP SYSTEM (IRSS) 27' HARBOR SECURITY BOAT (HSB) 7M RIBS 4.7M P470 COMBAT RUBBER RAISING CRAFT (CRRC)</p>	<p>40' POWER VENT (AMN1) 35' NS FOUNTAIN RACE BOAT 11M NSW RIB WILLARD 11M RIBS 24' HARBOR SECURITY BOAT (HSB) 13' BOSTON WHALER (WB)</p>																																						

- b. B. J. Metcalf et al., "Resistance Tests of a Systematic Series of U.S. Coast Guard Planing hulls", NSWCCD-50-TR-2005/063.

Carderock Division, Naval Surface Warfare Center

West Bethesda, Maryland 20817-5700

NSWCCD-50-TR-2005/063 December 2005
Hydromechanics Department Report

Resistance Tests of a Systematic Series of U.S. Coast Guard Planing Hulls

by
Bryson J. Metcalf
Lisa Faul
Elissa Bumiller
Jonathan Slutsky



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NSWCCD-50-TR-2005/063- Resistance Tests of a Systematic Series of U.S. Coast Guard Planing Hulls

- c. Evan Lee et al., "The systematic variation of step configuration and displacement for a double-step planing craft", Journal of Ship Production and Design, Vol. 30, No. 2, 2014.
- d. J. Almeter and W. Newman, "Performance improvements from a concave / convex planing surface", Transaction of SNAME (to be published).
- e. Videos for slamming model tests at high speed basin in DTMB.

